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Computational Analysis of Steel Joists at Elevated Temperatures

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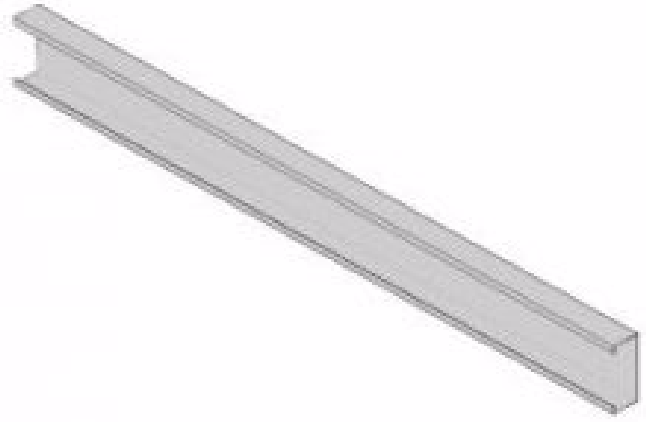
Steel Joists

- Joist - horizontal structural member typically used to support a floor or ceiling
- Type - Lipped Channel Section Joists (C-Section Joists)
- Modeling Program - Abaqus



Background

- Currently: Steel joist are tested experimentally by subjecting them to standard time-temperature fire curves

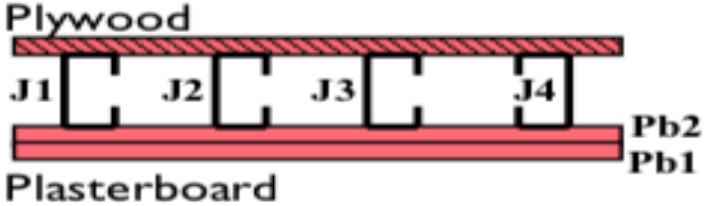
Limitations:

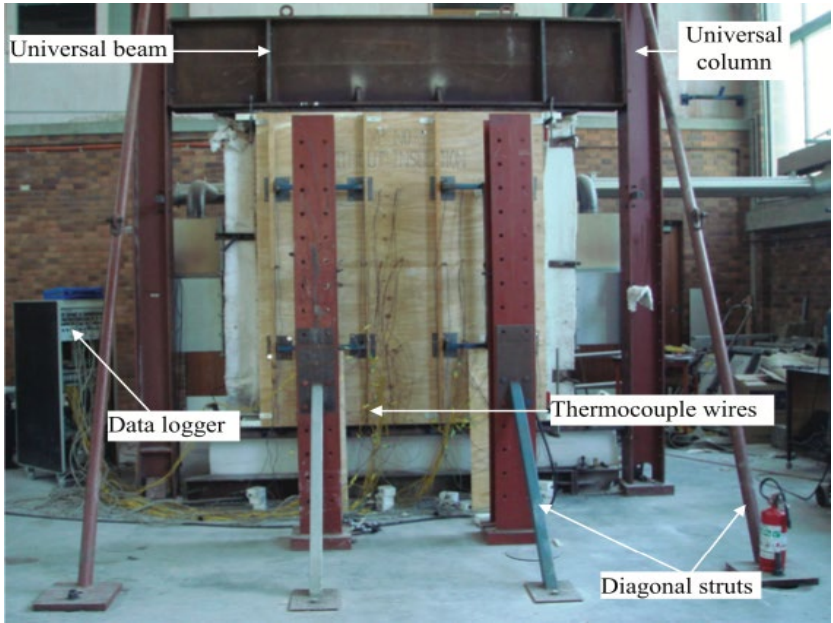
  - Tests are expensive
  - Limited number of joist configurations
  - Barely represent loading and support conditions of steel joists in a building
  - Impossible to estimate the performance produced by real fires

- Goal: Use computational tools to analyze steel joist behavior under fire

Experimental Testing

- Experimental tests conducted on a frame flooring system
- Flooring consisted of 4 joists, 2 tracks, plasterboard, and plywood
- Target load of 9 kN was applied to each joist
- A furnace created fire conditions based on standard fire curve
- Temperature, lateral deflection, and failure time were recorded

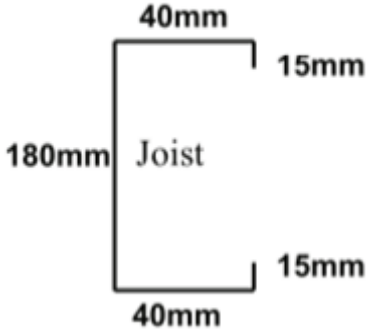


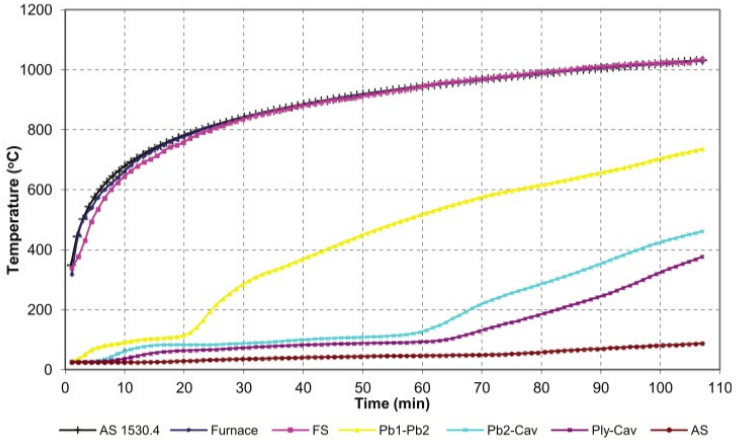


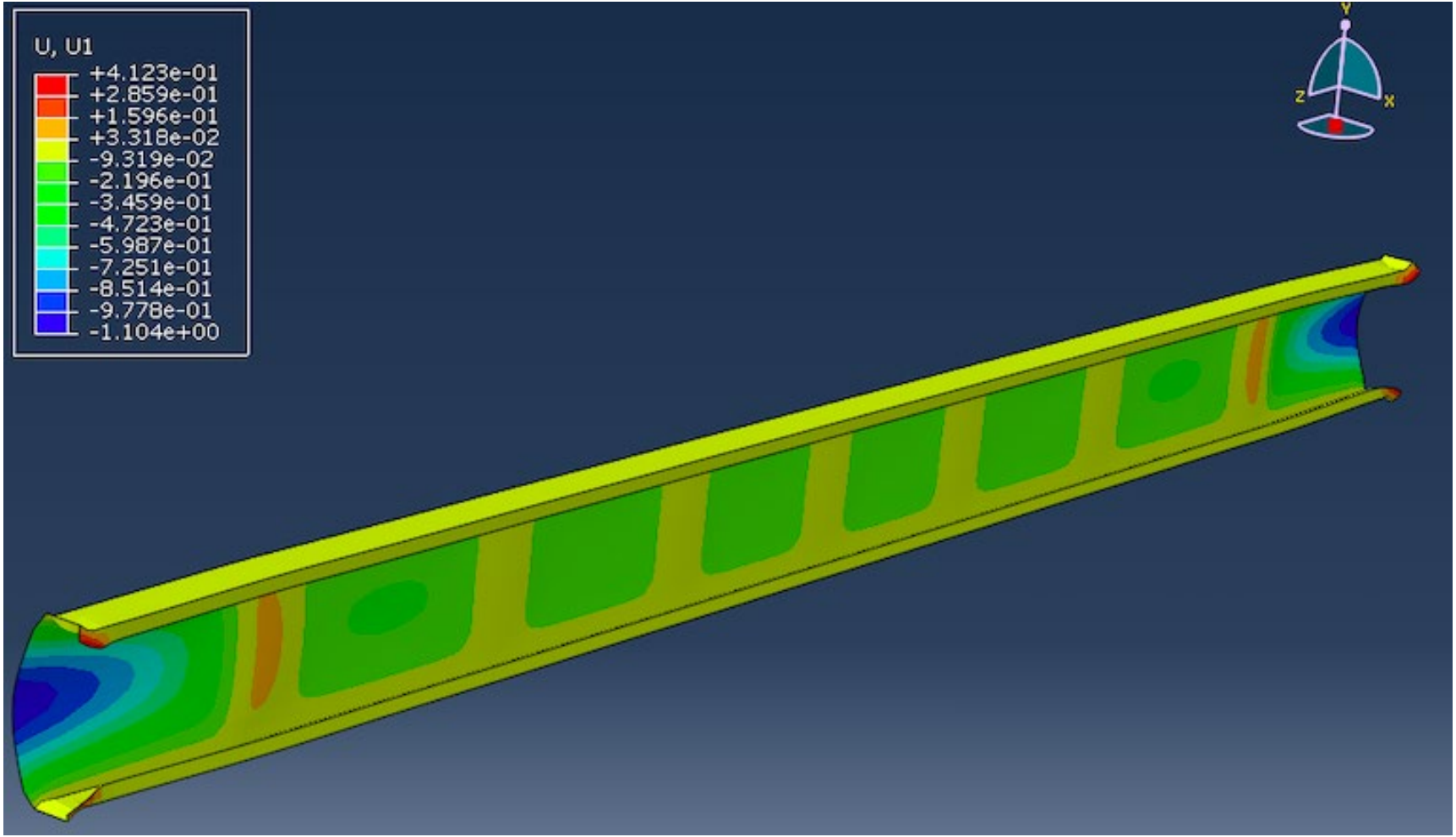
Experimental Results

Abaqus Model Criteria

- Joist Dimensions - 180 x 40 x 15 x 1.15 mm
- Material Properties:
  - Modeled as changing due to temperature except Poisson's Ratio which remains constant
- Boundary Conditions:
  - Model based on connections to plasterboard and plywood
- Load - 9 kN was uniformly distributed
- Temperature - modeled after experimental results



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Model Results

- The Abaqus Steel Joist Model produces results that are similar to the results produced from the experimental testing
- The error between the experimental and model results was calculated to be 5% or less

Failure Results			
Type	Experimental Results	Model Results	%Error
Time (minutes)	107	107.697	1%
Temperature	450, 400, 340	459.233	2%
Lateral Deflection (in)	0.967041516	1.01128	5%
Slope of Deflection	0.014629383	0.014704056	1%

Parametric Study

- Goal: To observe how each parameter affects the model and the results
- Conducted six parametric studies

Main Parameters:

- Material Properties - Poisson’s Ratio and Thermal Expansion Coefficient
  - Compare results with constant and varying values
- Changing the length of joist

Parametric Study Results

Material Properties Study					
Type	**Abaqus Model Results**	**Poisson's Ratio Results**	**% Difference**	**Thermal Expansion Coefficient**	**% Difference**
Time (minutes)	107.697	107.709	0%	108	0%
Temperature	459.233	459.367	0%	462.624	1%
Lateral Deflection (in)	1.01128	1.06816	5%	0.888062	13%
Stress	88.6983	87.9985	1%	86.7214	2%

Length Study							
Type	**Original Length 2400mm**	**Length 1500mm**	**Length 1000mm**	**Length 500mm**	**Length 3000mm**	**Length 3500mm**	**Length 4000mm**
Time (minutes)	107.697	108	108	108	87.0036	83.0564	77.1088
Temperature	459.233	462.624	462.624	462.624	326.797	296.813	263.327
Lateral Deflection (in)	1.01128	0.843906	0.685979	0.486279	0.88673	0.882696	0.838699
Stress	88.6983	86.31	71.79	65.6676	100.15	100.291	100.137

Conclusion

Experimental vs. Computational Study:

- Abaqus can accurately model steel joists under fire conditions
  - Prevents spending money for experimental testing
  - More joist configurations can be tested
  - Provides an easier method to model steel joists under fire

Parametric Study:

- Thermal Expansion Coefficient must vary with temperature to provide accurate results
- The length of the joist effects how and when it fails under fire

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